Portable Sensor System for the Analysis of Hazardous Chemicals in Water

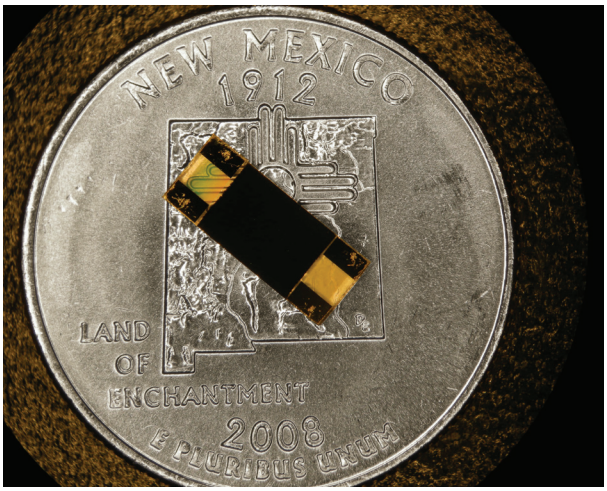

Figure 1: Photo of an NPC-coated 100 MHz SAW device on a quarter. Electrical contacts are made to the four large gold pads. The gold transducer lines between them generate and detect the acoustic wave.

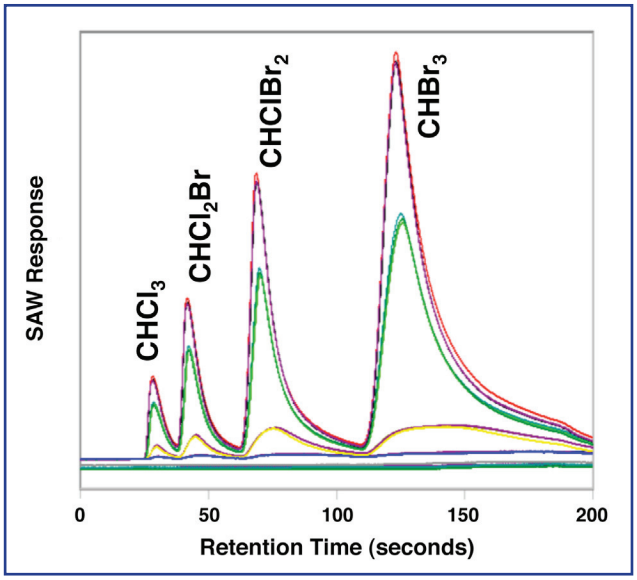

Figure 2: Phase-shift response from an NPC-coated SAW device for controlled exposures to various concentrations of THM mixtures. The retention time is from the gas chromatograph.

Nanoporous-carbon coatings on SAW devices enhance contaminate detection sensitivity by several orders of magnitude

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Two hundred million people in the U.S. rely on public utilities for safe, clean water. One hundred years ago, typhoid and cholera epidemics were common throughout our cities; disinfection processes eventually reduced these occurrences. In 1990, the Environmental Protection Agency (EPA) cited drinking water contamination as a major risk and indicated that disease-causing microbes (bacteria, protozoa, and viruses) were the greatest remaining health management challenge for drinking water suppliers. Indeed, over 500,000 cases of waterborne diseases in the U.S. were reported between 1980 and 1994. In 1993, a Milwaukee outbreak of a microbial pathogen, *cryptosporidium*, caused at least 50 deaths.

Ironically, antimicrobial treatment chemicals (*e.g.*, chlorine) react in water with trace natural organic matter to create chemicals, such as trihalomethanes (THMs), which are also hazardous to the public. Epidemiological and toxicological studies of high THM doses demonstrate adverse reproductive and developmental effects, while low dose studies are associated with bladder, rectal and colon cancers. Thus a major challenge for water suppliers is to balance the risks associated with microbial pathogens and the disinfection byproducts. The four THMs (chloroform, dichlorobromomethane, dibromochloromethane, and bromoform) are regulated by the EPA to a total maximum annual average of 80 parts-per-billion (ppb). Due to the difficulty in providing low-cost, simultaneous, individual measurements of each THM, all four THMs are regulated and reported together as a group on either a quarterly or yearly basis, depending on the size of the water utility. Existing THM detection methods for simultaneous,

individual measurements use large and expensive equipment, such as mass spectrometry.

To solve this detection problem, Sandia and Parker-Hannifin teamed up to develop a low-cost, portable, highly-sensitive system for simultaneous, individual hazardous chemical detection in water. It uses a purge and trap technique, followed by isothermal gas chromatography that separates the four THMs that are then detected with a nanoporous-carbon (NPC) coated 100 MHz surface acoustic wave (SAW) sensor device fabricated on a quartz crystal (Figure 1). As the separated chemicals sorb into the coated surface and add weight, the SAW sensor measures a reduction in the speed of a sound wave launched from one side of the crystal to the other. The device responds as a function of analyte concentration, measured as a phase shift in the wave over a fixed length. The NPC coatings greatly increase device response by enhancing the available surface area for chemical sorption. NPC coatings are reproducible, sensitive, thermally and chemically stable for long-term use, and appear to outperform all other known coating materials by several orders-of-magnitude (References 1,2).

Figure 2 demonstrates the detection of each THM from fixed mixtures that are separated via gas chromatography and detected by the SAW device. Chloroform elutes first, followed in succession by each chemical in order of molecular weight. The integrated response peaks are plotted versus the known concentration for each THM in Figure 3. A functional power-law behavior demonstrates that NPC-coated SAW devices have limits of detection less than 1 ppb for chloroform, and nearly 1 part-per-trillion for bromoform. Figure 4 illustrates the compact portable prototype system from Parker-Hannifin.

The low-cost, portable system for hazardous chemical detection represents a great advance for the health and safety of the public's clean water supply. It is the only portable sensor system with ppb detection levels and separability of all four THMs, greatly enhancing the information necessary for epidemiological and toxicological studies of these hazardous materials. Furthermore, tests demonstrate the ability to readily detect at least nine different chemicals in a typical water sample. Calibration for these chemicals will enable the device to monitor each contaminant individually.

References

1. M. P. Siegal, W. G. Yelton, D. L. Overmyer, and P. P. Provencio, "Nanoporous carbon films for gas microsensors", *Langmuir*, **20**, 1194 (2004).
2. M. P. Siegal and W. G. Yelton, "Nanoporous-carbon coatings for gas-phase chemical microsensors", *Advances in Science and Technology*, **48**, 161 (2006).

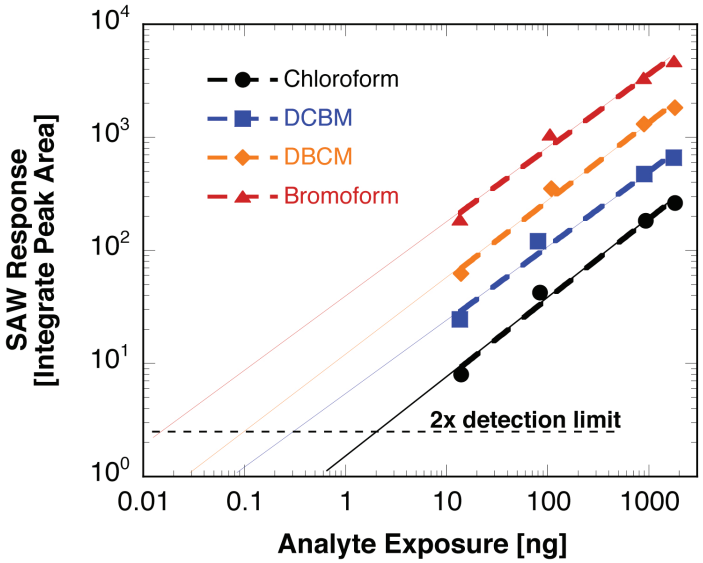

Figure 3: SAW response vs. analyte exposure. (Note: 12 ng ~ 1 ppb.) The dashed line represents the SAW device detection limit, due to signal-to-noise. The detection limits for $CHCl_3$, $CHCl_2Br$, $CHClBr_2$ and $CHBr_3$ are 0.16, 0.026, 0.009, and 0.001 ppb, respectively.

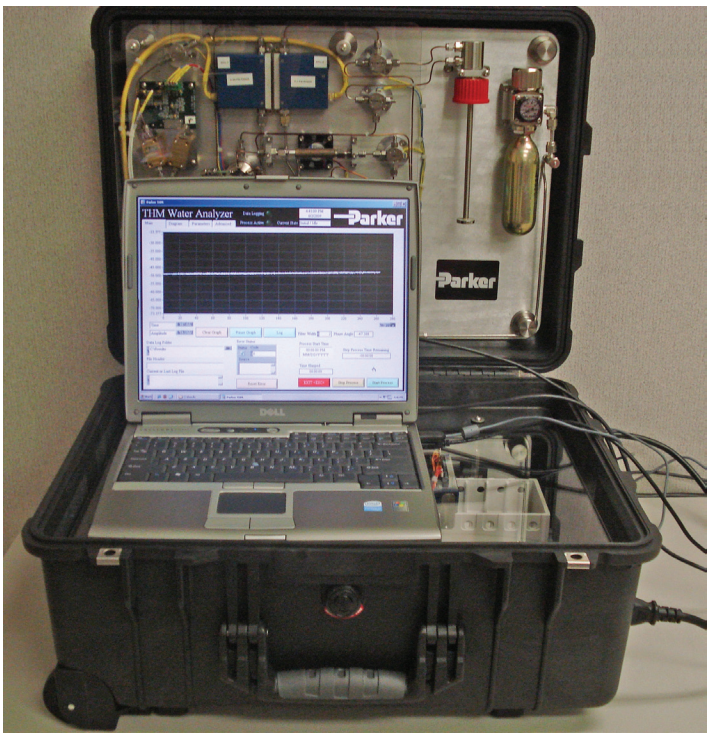

Figure 4: Briefcase version of portable detection system built by Parker-Hannifin that includes power supply, laptop computer, water sampling, purge and trap, isothermal chromatography, and SAW sensors for detection.

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